FIRE MODELING WITHOUT TEARS: WHAT IS ITS FUTURE IN FORENSIC FIRE INVESTIGATIONS?

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Summer Texas Fire Investigation Forum

Houston, Texas

Sponsor: Texas Department of Insurance

State Fire Marshal's Office

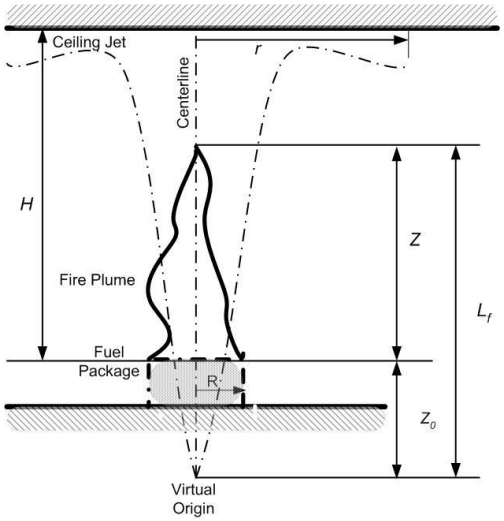
What questions will be answered?

- ***1. What exactly is a fire model?***
- ***2. How is Fire Modeling Applied to Forensic Fire Investigations?***
- ***3. What Questions a Fire Model Could Potentially Resolve***
- ***4. How Accurate is Fire Modeling?***
- ***5. What is the future of fire modeling in forensic investigations?***

Based upon materials from textbook Chapter 6, "Fire Modeling," in *Forensic Fire Scene Reconstruction* (3rd Edition) by D.J. Icove, J.D. DeHaan, and G.A. Haynes, Prentice Hall, 2013.

1. What is a Fire Model?

- Fire models are mathematical models that *emulate the impact of fires* and *not the physical fire*
  - Smoke detector and sprinkler activation times
  - Flame heights and smoke development
  - Time to flashover
  - Fire pattern damage
  - Egress time
  - Time to incapacitation



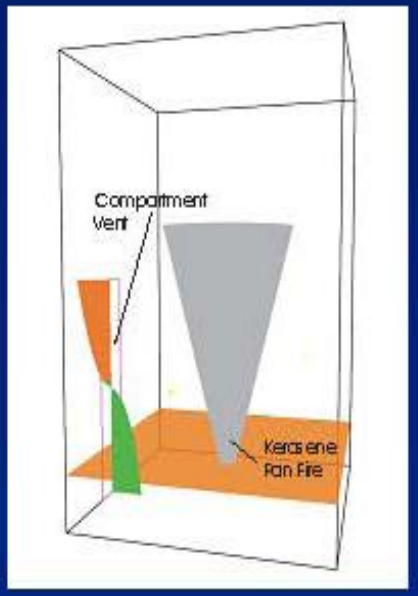
Three Standard Tiers of Fire Models (Analytical, Zone, Field)

Hand Calculations

$$T_g - T_\infty = 6.85 \left(\frac{\dot{Q}^2}{A_0 \sqrt{H_0} h_k A_T} \right)^{1/3}$$

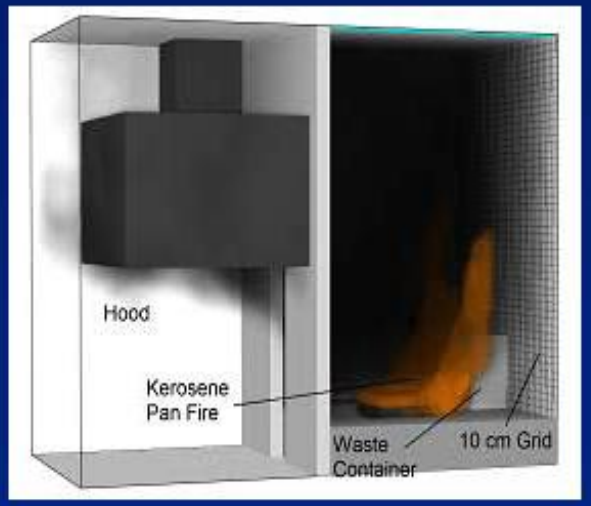
McCaffrey, Quintiere, Harkleroad (MQH)

Two-Zone Models



CFAST, NIST

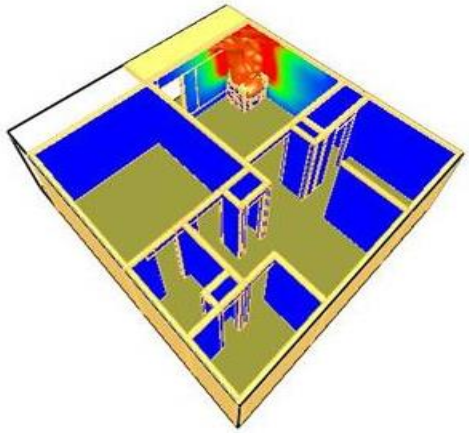
CFD



FDS, NIST

2. How is Fire Modeling Applied to Forensic Fire Investigations?

- *Assessing* the "working hypotheses" in the Scientific Method
- *Interpreting* fire ignition, growth, development, and resulting damages
- *Reviewing* and *interpreting* the effectiveness of fire protection codes, standards, specifications, and designs
- *Evaluating* the effectiveness of active and passive fire suppression
- *Evaluating* human tenability in fires



3. What Questions a Fire Model Could Potentially Resolve

- **Criminal**
  - Was the fire a result of a criminal act or omission?
- **Civil**
  - What and how did these products/parties contribute to the loss?
  - Are there any legal grounds for recourse and/or recovery?
- **Professional/Design**
  - What can be learned from this fire or explosion loss to avoid future incidents, change code, and improve designs?

4. How Accurate is Fire Modeling?

- "***Comparison of Three Fire Models in the Simulation of Accidental Fires***,"G. Rein, A. Bar-Ilan, and A.C. Fernandez-Pello, University of California at Berkeley; and N. Alvares, Fire Sciences Applications, San Carlos, California, 2004.

- Study applied and compared the predictive capabilities of Analytical, CFAST Zone, and FDS Field Models to three accidental fires
- Findings were these three models *produced results in relatively good agreement, particularly in early stages of fire development*

Case Study – Pittsburgh House Fire

Reference: *A.M. Christensen and D.J. Icove,* "The Application of NIST's Fire Dynamics Simulator to the Investigation of Carbon Monoxide Exposure in the Deaths of Three Pittsburgh Fire Fighters," *Journal of Forensic Science, Jan. 2004, Vol. 49, No. 1.*

The Pittsburgh House Fire Victims

- Realized they were exhausting their air supply
- Were unable to find an exit
- Attempted “buddy breathing”
- Were eventually rendered unconscious due to carbon monoxide exposure or oxygen deficiency
- FEMA report estimated their time to incapacitation could be up to 40 minutes

The Firefighter Autopsy Reports

- Two firefighters
  - Carboxyhemoglobin of 40-50%
  - Cause of death = inhalation of CO

- One firefighter
  - Carboxyhemoglobin of 10%
  - Cause of death = oxygen deficiency

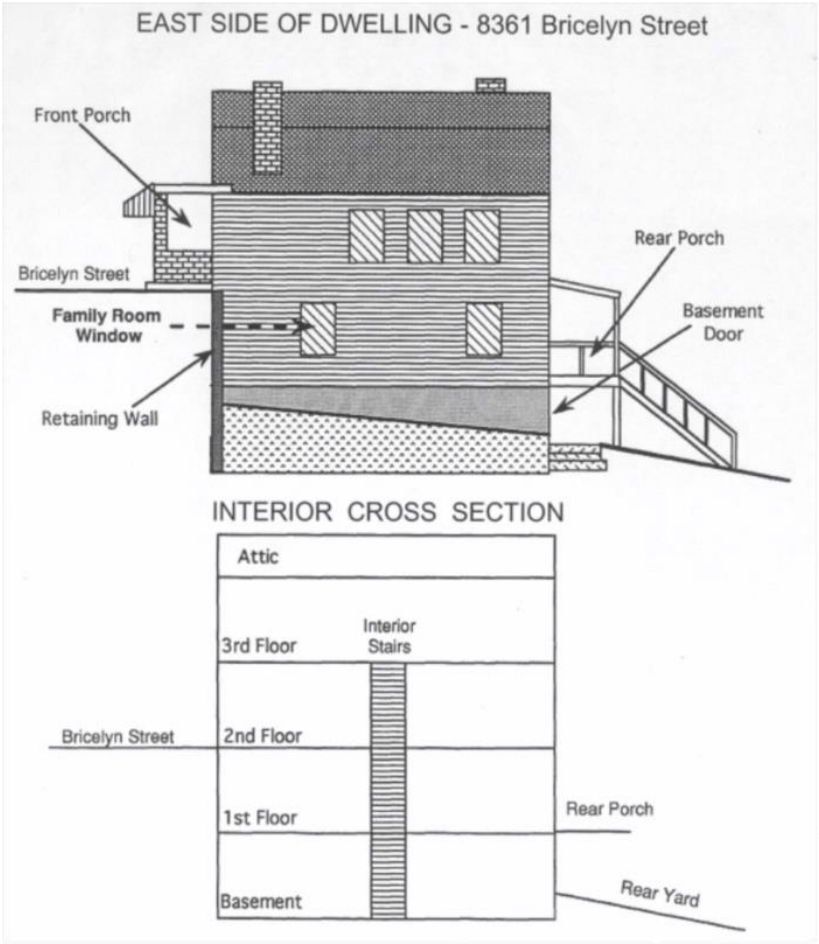
Analytical Model Estimating Time to Incapacitation (Stewart Equation)

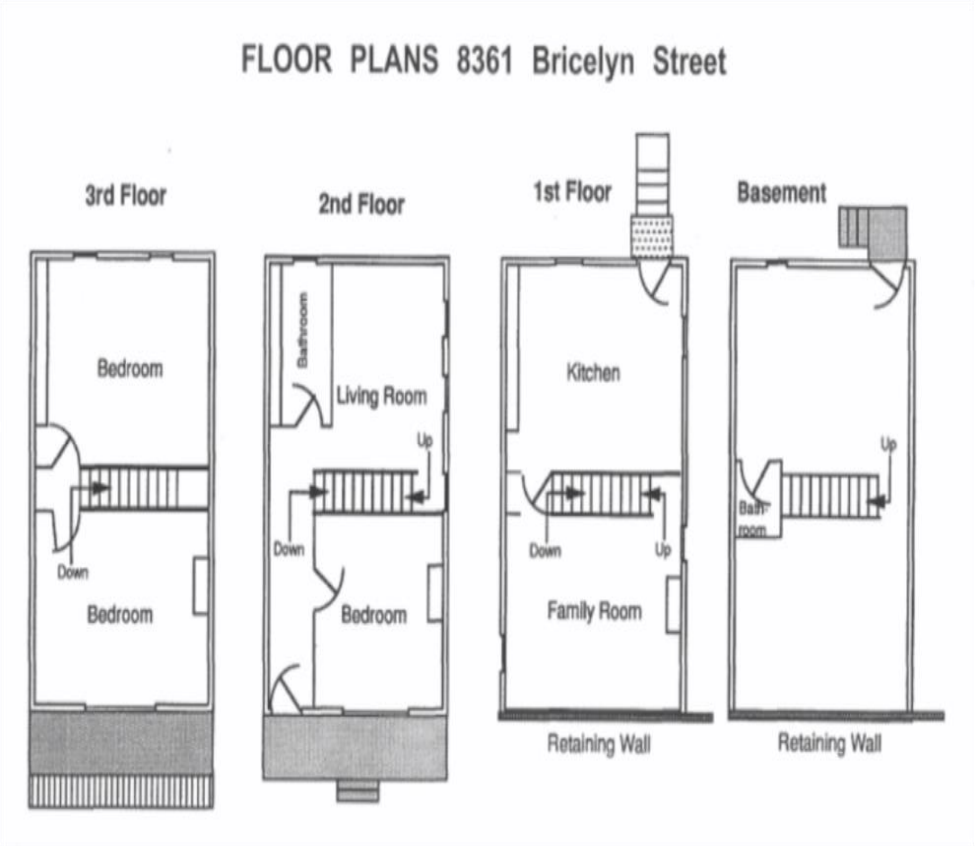
$$COHb = (3.317 \times 10^{-5})(CO)^{1.036}(RMV)(t)$$

Where:

- COHb = Carboxyhemoglobin in the blood (percent)
- CO = Level of carbon monoxide (ppm)
- RMV = Respiration minute volume (L/min)
- t = Time of exposure (min)

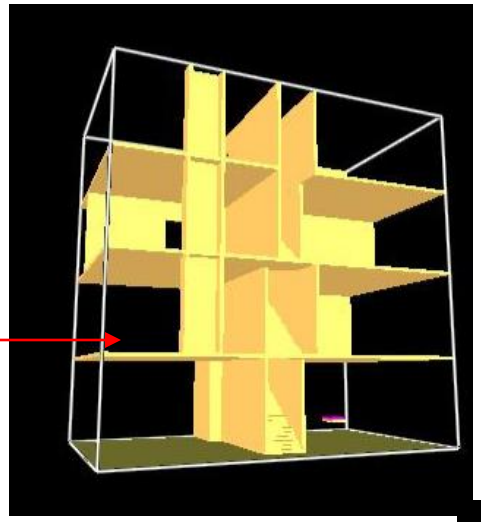
Modeling the Pittsburgh House Fire

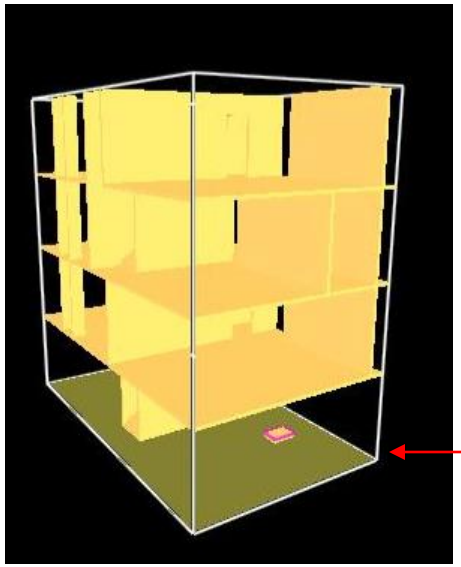




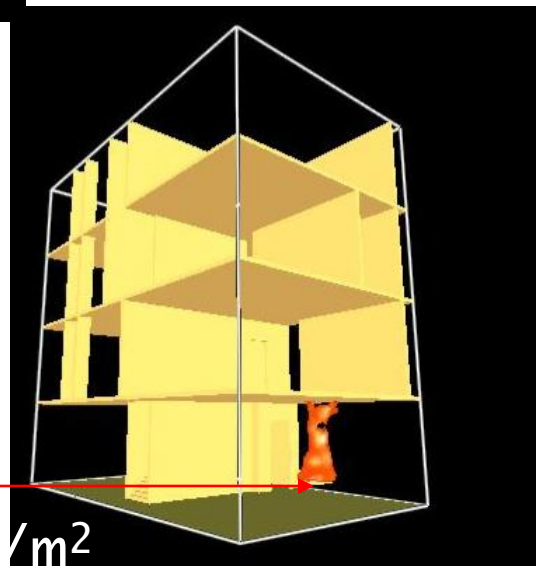
Modeling the Pittsburgh House Fire

Reconstructed dwelling

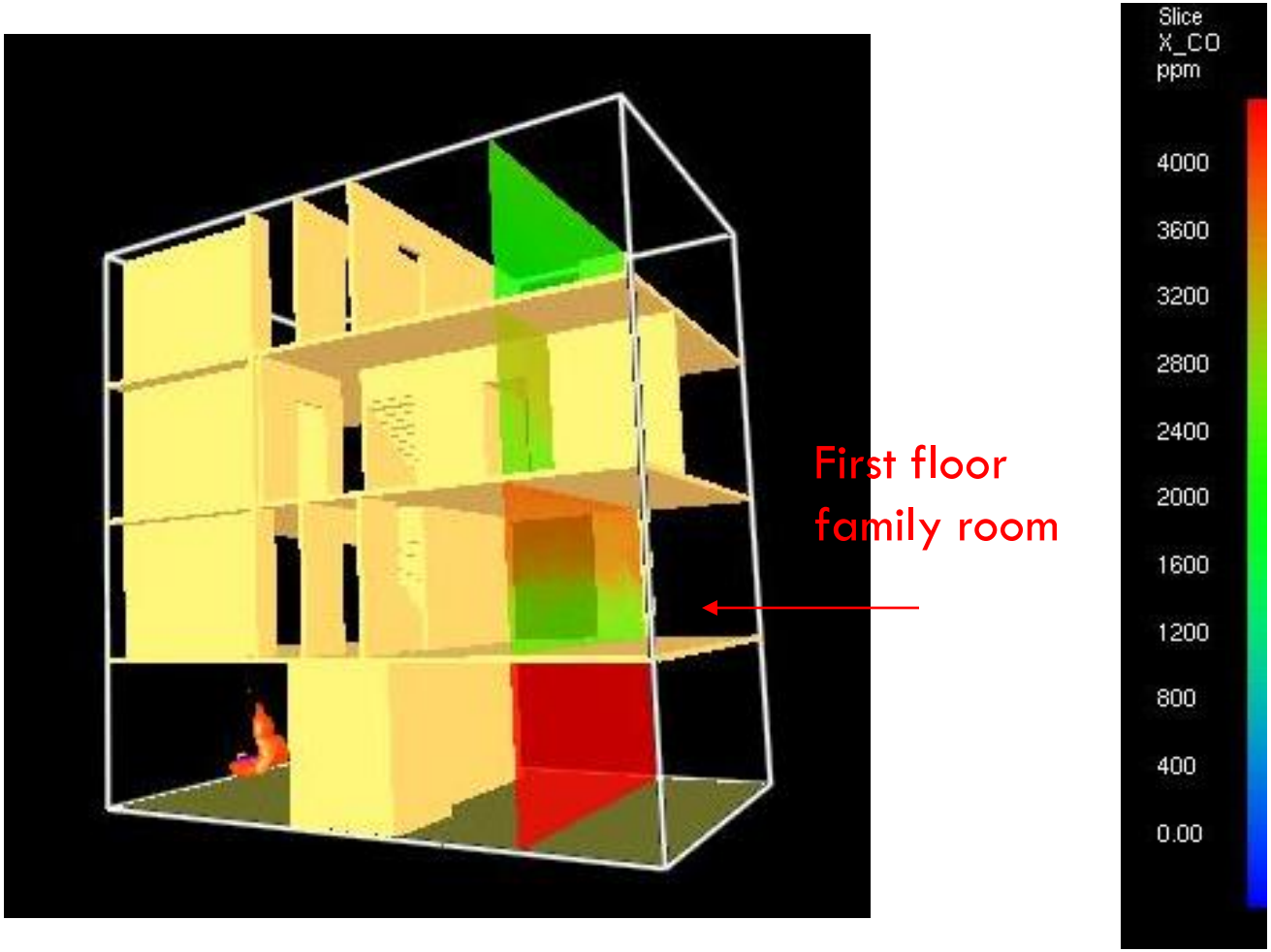




"Burner" (point of origin)



Carbon Monoxide Level on 1st Floor



Calculating Time to Incapacitation

$$COHb = (3.317 \times 10^{-5})(CO)^{1.036}(RMV)(t)$$

Known or estimated

COHb = 45%

CO = 3600 ppm

RMV = 50 L/min

Equation solved for t

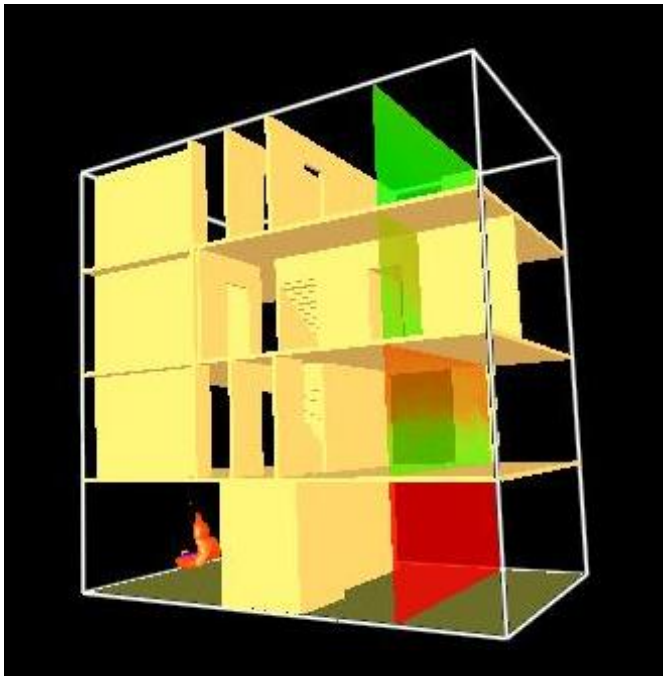
t = 5.6 minutes

Implication of Results

Estimate based on:	Time to incapacitation:
FEMA report	0-40 minutes
Computer model and other data	< 6 minutes

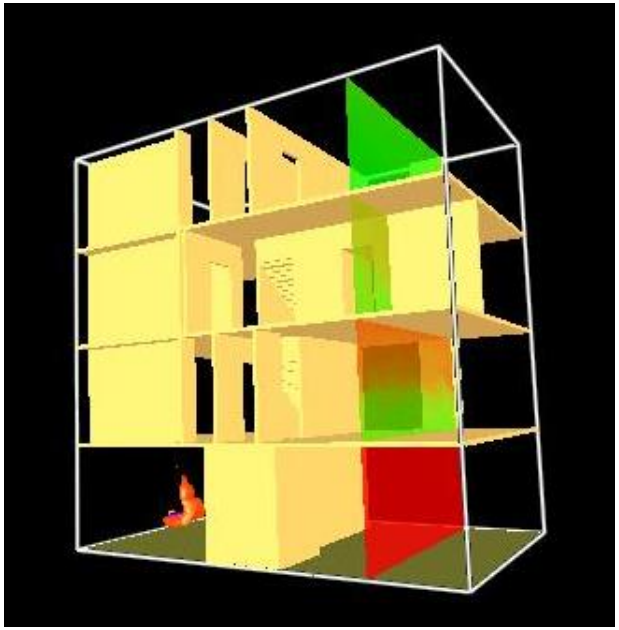
Study Findings and Conclusions

- Demonstrates potential for the *combined efforts of investigators and engineers* to improve forensic fire death investigations
- *Documented successes* with fire modeling will increase proficiency and improved models



5. What is the Future of Fire Modeling?

- Will fire investigators be adequately trained in fire dynamics to appreciate its application?
- Will public agencies hire experienced fire protection engineers to apply this science to forensic investigations?
- Will fire modeling be developed to pass the scrutiny of *Daubert/Robinson* Challenges in Texas?



So, have we answered the commonly asked questions?

- What is a fire model?
- What areas where fire modeling can assist forensic fire investigations?
- What are the realistic and reliable results that can be expected?
- What is the future of fire modeling?

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